2. Vergence and vergence eye movements

2.1 Introduction

Eye movements can be classified in various ways. Carpenter (1977) divided eye movements into catching or fast movements, such as saccades and the quick phase of the nystagmus, and holding or slow movements, such as vestibular movements, smooth pursuit and vergence.

Another division is between conjugate and disjunctive movements. Saccades, for example, are conjugate movements and vergence movements are disjunctive movements. Below we shall focus on disjunctive movements (vergence). See figure 2.1.

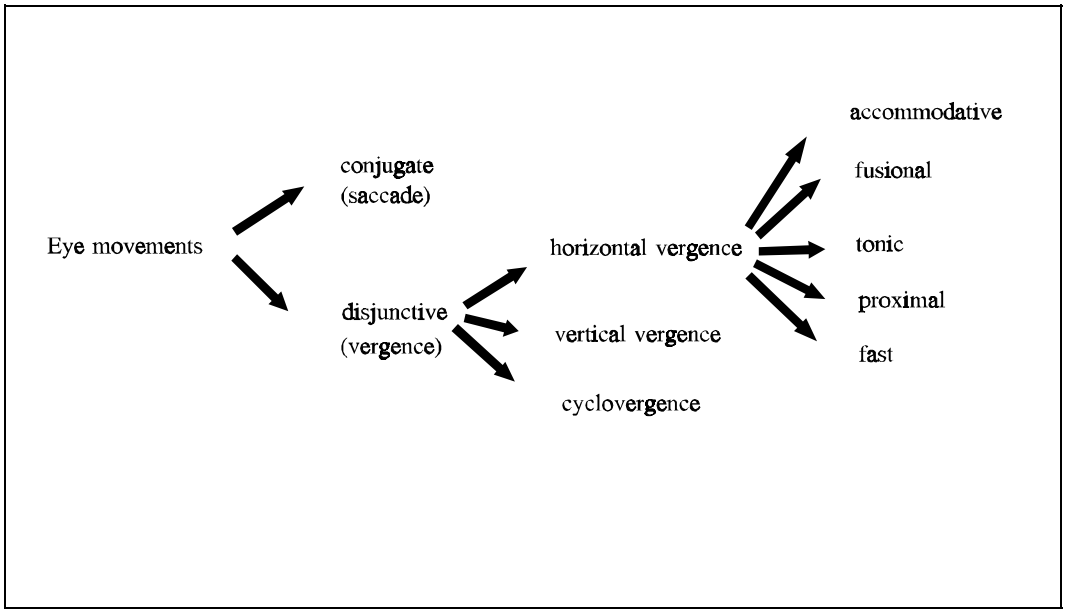

figure 2.1
Classification of eye movements.

Throughout this thesis, vergence refers to the hypothesized underlying neuronal process. Convergence and divergence refer to the actual eye movements.

In 1893, Maddox divided horizontal vergence in four different types:
- accommodative vergence;
- fusional vergence;
- proximal vergence;
- tonic vergence.

An alternative classification of vergence was given by Crone (1979), who divided horizontal vergence into three mechanisms:

1. motor fusion (the F system);
2. synkinesis of near fixation, accommodation and miosis (the S system);
3. the slow mechanism of orthophorization, the O system

See also section 2.5.

In recent years, several authors have reported vergence eye movements which were faster than the fusional or accommodative vergence eye movements recorded in the usual classical experiments, such as:

- vergence mediated by saccades (Enright, 1984);
- rapid vergences (Erkelens, 1986; 1991);
- proximal vergence (Wick and Bedell, 1989);
- vergence saccades (Hyson, 1983).

These vergence movements have in common that they were recorded in more complex (natural) viewing conditions.

In this study the division of vergence types is based on the way the movement can be evoked. Therefore the different types of vergence are described according to the following classification:

- by disparity (section 2.2);
- by blur (section 2.3);
- in a complex stimulus environment (section 2.4).

2.2 Disparity Vergence

2.2.1 Fusional vergence

2.2.1.1 Normal fusional vergence

Fusion consists of both motor fusion and sensory fusion. The movement that serves to bring the images on corresponding retinal points is called motor fusion. With the following experiment motor fusion, or fusional vergence, is described (figure 2.1). A subject is binocularly fixating a visual target. A weak horizontal prism is suddenly placed in front of one eye; the right eye in this case (see figure 2.1[a]). The prism causes a shift of the image, which results in disparity. This disparity leads to a vergence movement (see figure 2.1b and 2.1c from one of our experiments). The subject is generally unaware of this (Carpenter, 1977).

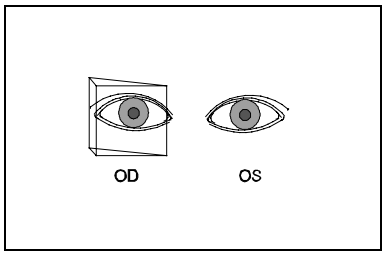

figure 2.1[a]

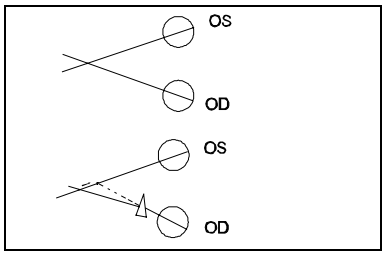

figure 2.1[b]

In this example, just after the beginning of the vergence movement, a fast versional movement, a saccade, takes place. The saccade is evoked by the process of intermediate localisation, caused by the displacement of the prism in front of only one eye. After the saccade the vergence movement becomes more obvious (see figure 2.1[c]). By this (fusional) vergence movement, the image is again projected on corresponding areas in the retinae of both eyes (areas with a comparable localisation in space). The stimulus for this fusional vergence is disparity; therefore, the term disparity vergence will often be used instead of fusional vergence. Such a movement is illustrated in figure 2.1[c].